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# THE CONNECTION BETWEEN GEOLOGY AND SCENERY.

BY THE REV. H. H. MOORE, M.A.,
*Vicar of St. John's, Darwen.*

## INTRODUCTORY.

IN a previous paper I advanced several reasons for the study of geology, and one of these was that the geology of every district is the cause and explanation of its scenery. I will now try to prove and illustrate this statement by reference to the chief geological formations and types of scenery in our own country.

But before proceeding to speak in detail of the scenery I must just give a brief outline of the earth's history, for we cannot properly understand and explain even one of the different formations or classes of rocks that constitute the earth's solid crust without going back to the creation. "One age is so linked to another that, if we would understand the whole history of even one hill or one valley, we must go back to the very earliest period at which its underlying rocks began to coagulate beneath the waters of the all-producing ocean." Considering the interconnection and interdependence of all things in nature, this is not surprising, for, as it has been well said, "There is no picking up even a pebble by the brookside without finding all nature in connection with it." Let us then begin at the beginning. Tennyson, in "The Princess," correctly describes the nebular theory of the evolution of the solar system.

> "The World was once a fluid haze of light,
> Till towards the centre set the starry tides,
> And eddied into suns that wheeling cast
> The Planets—"

The earth therefore is formed of the same elemental world-stuff as its sister planets and their central sun. At first our globe was in a state of incandescent heat. But it was constantly giving off its heat into the cold of outer space. The external surface naturally cooled first and in time formed a hard crust or shell, such as forms on the surface of molten lava as it cools. For some time this crust while thin would retain some of the heat communicated to it from the molten interior. When the temperature cooled down to a certain point the gases surrounding the globe would be enabled to combine and water would be formed, which would rest on this heated but gradually cooling crust. The waters would be raised to boiling point by contact with the heated crust, and these boiling waters must have given off enormous quantities of steam and vapour which, as they reached the cold of outer space, would be condensed and precipitated again on to the surface of the globe as mists and perpetual rains. The planet Jupiter has only just reached that stage, because, being so much bigger than the earth, it has taken longer to cool down to that point. As the crust of the earth thickened and cooled to a greater extent, the steam and vapour would no longer be generated; the greater part of the watery vapours would condense and fall upon the earth, and there remain on its now cooler surface, whilst the waters that remained in the atmosphere would be only so much as the increasing heat of the gradually condensing sun would be able to evaporate and keep in suspense. As long as the crust of the earth continued in the warm state the heat and the incessant motion of the boiling waters, combined with the effect of acids (which must have been present in the waters to an enormous extent), would disintegrate portions of the rocky crust or bed on which the waters rested. This disintegrated matter, after being long kept in motion and suspense amid the boiling, surging waters would at last be allowed to settle on the bed of the ocean, and thus the materials of the very first sedimentary rocks would be formed. In the process of cooling the earth would necessarily contract, and therefore the solid outer crust would fall in on itself; some portions would be forced up to a great height and others would subside and form deep depressions. The waters of the once universal ocean would necessarily leave the elevated portions of the land, and would flow down the slopes into the hollows, and thus the earth's surface became divided into land and sea. The rocks which were first upheaved must therefore have consisted of portions of the igneous crust of the earth and of the sediments deposited on the bed of the once boiling ocean; consequently they had been subjected to the influences of heat, water, and pressure, and thereby hardened and crystallised; in some cases they might also have a stratified structure. The frequent fractures of the solid crust of the earth caused by its constant contraction would permit the waters that settled in the depressions to leak down into the lower portions of the crust, and there come in contact with intense heat. The formation of steam would ensue, and by its enormous expansive force portions of the rocky crust would be lifted up and fractured, and volcanic vents would be made, from which steam, fire, ashes, and molten rock would be ejected. Wherever the volcanic heat and the heated matter came in contact with other rocks the latter would be burnt, baked, and crystallised. Over and over again the oscillating movements of the earth's crust caused by contraction and volcanic forces have alternately upheaved and submerged every portion of the earth's surface; while in one part a continent or mountain range was being sunk and submerged, in another part a sea bottom might be rising to form a new continent. We see then that there have always been these two causes operating more or less actively to produce irregularities in the surface of the earth by pushing up some portions and depressing others, viz. (1) the contraction and consequent fracturing, crumpling, and puckering of the rocky crust, and (2) the volcanic action of subterranean forces coming in contact with water. But at the same time there have always been two other influences at work to degrade the elevated portions of the land surface and to fill up its hollows—(1) marine agencies; (2) atmospheric agencies. As the upheaved portions of land successively came to the surface the waves of the sea, impelled by winds and currents and tides, would attack them violently and ceaselessly, and would disintegrate and wear them away at varying rates according to the comparative hardness or softness of their texture. First of all the sea would plane away or break the rising ridges; then, as these were lifted above its reach, it would wear away the slopes of the still rising land and form cliffs; then it would batter down and eat away the cliffs till they too were lifted beyond its reach; then it would carry away and redistribute the shingle and sands which it had accumulated at the foot of the cliffs. But even after the rising land surface got safely above the power of the sea, it found still other and more dangerous assailants, viz., atmospheric agencies. The gases of the atmosphere, wind, cold, heat, moisture, frost, the eroding, transporting power of running water, the gouging, grinding powers of glaciers, all combined to wear away elevations and prominences, and to carry the materials into the valleys, rivers, lakes, and seas, which occupied depressions. All these agencies of course, and especially running water, would have the most destructive effects on the softer rocks and hollows and steep slopes. The worn-away materials of the upheaved land masses were thus deposited in the surrounding sea, they accumulated there, and became compacted by the superincumbent weight, and at last, in their turn, were again upheaved to form a still newer continent. As Beattie says:

> "Earthquakes have raised to heaven the humble vale,
> And gulfs the mighty mountains' mass entombed,
> And where the Atlantic rolls wide Continents have bloomed."

And Kingsley says, "Time after time the floor of the ocean has been paved with the mountain tops, and the adamant of the seemingly eternal hills has been changed to sand and potter's clay." And, as Tennyson says:—

> "There rolls the deep, where grew the tree,
> O Earth what changes thou hast seen!
> There, where the long street roars, hath been
> The stillness of the central sea."

In this way the surface of the land now forming the British Isles has been many times alternately depressed and elevated, and overlaid with many kinds of sedimentary deposits, until the total thickness of all the different layers or formations, if placed one on top of the other, would amount to about twenty miles. You will now understand how it is that there are the following three classes or kinds of rock: (1) Igneous rocks, which are sub-divided into two classes—volcanic and plutonic. These include lava, pumice, scoriœ, granite, porphyry, greenstone, basalt, etc. (2) Aqueous or sedimentary or stratified rocks, being those whose component materials have been worn away from exposed land surfaces and deposited layer upon layer under water. (3) Metamorphic rocks, being those sedimentary or stratified rocks which have been so acted upon by the combined agencies of heat, water, and pressure, or by the proximity of igneous rocks in a heated condition, that they have lost much of their stratified character and have been metamorphosed, or changed, into hard, structureless, crystalline masses. By some geologists granite is included among the metamorphic rocks as the most crystalline and amorphous of this class, and as probably representing the ultimate stage of the process. You will also now understand how it is that the sedimentary rocks differ in their constituent materials and structural arrangement according to the composition of the rocks from which they were originally derived, and according to the circumstances under which they were disintegrated, deposited, compacted and displaced. But whatever variations in other respects they may be subject to, there is never any change in the relative order and position of the strata. The following are the names of the different formations in the order in which they invariably occur, beginning with the lowest and oldest, and coming upwards to the newest: The Laurentian, or Archæan, or Pre-Cambrian, this is the lowest and oldest of all the formations. It is not extensively exposed in the Eastern Hemisphere. It forms the foundation of the British Isles, and on it all the other formations rest, but it comes to the surface only in Sutherland, the Hebrides, the Malverns, the Wrekin, and Charnwood Forest. It is in the Western Hemisphere that this formation has its grandest development. There rocks of this formation occupy an immense area of the northern part of North America, of which they form the skeleton or nucleus, round which all the rest of the area of the Continent has been formed subsequently by a succession of later deposits and upheavals. These Archæan rocks have been subjected to such intense pressure and heat that the sandstones, shales, clays, and limestones of which they consist have been baked and crystallised and metamorphosed so that they have been turned into gneiss, micaschist, hornblendeschist, quartzite, and marble. In fact they differ in no way from igneous rocks, except that they sometimes show a bedded or foliated structure. Next come the Cambrian, the Silurian, the Devonian, the Carboniferous, the Permian, the Triassic, the Jurassic, the Cretaceous, the Eocene, the Miocene, the Pleiocene, the Pleistocene, and the modern surface deposits.

You will also now understand why you do not find all the strata lying horizontally and regularly one atop of another like the leaves of this book in unbroken order and level. For in the repeated upheavals and depressions and dislocations which every portion of the crust of the earth has experienced, the rocks have been bent, fractured, crumpled, wrinkled, tilted up at every angle, and even folded back over one another in repeated folds. Often one stratum has been tilted up perpendicularly while it sank to form a new sea bed, and on its upturned edges other strata of sediments have been deposited horizontally. You may see such instances at Thornton Force, near Ingleton, and at the Moughton Fell Slate Quarries, in Ribblesdale, near Settle, where the limestone strata are lying horizontally on vertical slaterock of the Silurian formation. And in limestone quarries round Sawley you can see the layers of rock contorted and curved as if they had been only folds of paper or cloth. Let us now take a glance at the

### History of the Origin of the British Isles,

for we cannot understand its present aspect without tracing its past history. We must go back in imagination to ages of untold antiquity, when the North Atlantic Ocean did not exist, but its place was occupied by a continent which on the west stretched as far as what is now the coast line of North America and on the east approached the present coast line of the British Isles and North West Europe. As Beattie says—

> "Where the Atlantic rolls wide continents have bloomed."

Where the British Isles now stand was a vast and deep bay round the north, west, and south-western sides of which the coast of Atlantis curved. In this bay the materials eroded from the Archæan rocks of the continent of Atlantis were deposited in order to contribute to the formation of the future British Isles. These sediments were hereafter to constitute the Cambrian and Silurian formations which together represent ten miles thickness of sedimentary matter. In due time occurred one of those great interchanges of level between different parts of the earth's crust which have been so frequent. The Atlantic continent gradually sank beneath the level of the sea and became the bed of the present Atlantic Ocean, and simultaneously and proportionately portions of the sea bed were elevated where now stand the British Isles and W. Europe. The line of fracture or separation seems to have been just west of the British Isles for immediately after leaving our Western coast line we find the bed of the Atlantic drops suddenly to its greatest depth, and then as we go still further westward it rises again and becomes a plateau at only a moderate depth, and as such extends nearly to the American coast.* When the British submarine plateau was upheaved the line of its first and principal elevation was mainly that of the present western coast of our islands. It does not seem to have risen as a level continuous ridge, but as a number of separate masses. We must therefore think of the British Isles at first as an archipelago of insulated mountain groups divided by channels and straits. Many subsequent elevations and depressions took place during countless ages before all the hill ranges of our islands were upheaved and sculptured and worn, to assume their present shape and aspect. Time will not permit us to trace in detail all these changes. For the present I have gone far enough in the geological evolution of the British Isles to serve my immediate object, which is to make you understand that it was the western portion of the British Isles which was first upheaved, and that the rocks thus early upheaved belonged to the oldest formations. Because they were the oldest and basement strata they had necessarily been most acted on by pressure, heat, and water, and consequently were the hardest and most crystalline. This one fact is a master key to the explanation of several of the most striking physical features of our island.

## OUR COASTS AND THEIR SCENERY.

In the first place the very existence of our isles depends upon this geological fact. For the hardest formations, having been uplifted on the Western edge, serve as a mighty breakwater against the destructive attacks of the stormy Atlantic Ocean, protecting the newer and softer formations which have been deposited on the eastward slopes of the main western axis of elevation. Suppose now that the line of upheaval and exposure of the oldest and hardest rocks had been on our east coast, and that the newer formations had sloped from it towards the Atlantic. We see at once that these formations being composed of softer and less compacted materials, being at a lower level, and having easier slopes, could not long have survived the destructive power of the Atlantic waves and storms, so that there would soon remain only a narrow ridge of the harder rocks where our present eastern coast line runs. The present east and south-east coast line being formed of comparatively soft rocks and lowlands cannot withstand even the infinitely less powerful attacks of the North Sea. The whole eastern coast of England is even now being worn away at the rate of four yards a year. The longer resistance and survival of some portions like the projecting headland of Flamborough is simply due to the presence of a rather harder rock, viz., the "basset" or upturned edge of the chalk formation, which runs diagonally through England from Dorset to Yorkshire. Where it strikes the south shore we find the promontory and cliffs of St. Albans Head; where its inlying edge that surrounds the Wold comes on the straits of Dover we find the massive Shakespeare's cliff. It is the comparative hardness of the chalk also that has preserved the Isle of Wight from destruction. But none of the formations of the eastern and south-eastern parts of England could have existed if they had been exposed to the same destroying power as the west coast. It is fortunate then for us that we have on our western coasts our highest lands and hardest rocks to protect our island from destruction.

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* The bed of the ocean south-west of the British Isles descends to a depth of 2625 fathoms at a distance of about 400 miles from the Lizard. On the western side of the Atlantic is a similar depression, which, south of the banks of Newfoundland, reaches 3825, and probably represents a fracture produced contemporaneously with the elevation of the Alleghanies.

The western and north-western coasts of Scotland are composed of igneous rocks and the most metamorphic of the sedimentary rocks; *e.g.*, the north-west coast of Sutherland and the outer Hebrides from the Butt of Lewis to Barra Head are chiefly formed of the fundamental or Laurentian gneiss. St. Hilda, the most westerly of the outer Hebrides, consists of syenite. The Isle of Harris is granite. Skye and Mull, with much of the neighbouring and intervening coast, as well as others of the inner Hebrides, are largely composed of gneiss and granite. The well-known Isle of Staffa, with its peculiar columns of basalt, is a remnant of a once extensive sheet of lava emitted from the now extinct volcano of Mull during the Eocene period. The Red Hills of the Isle of Skye are pink syenite. The Cuchullin Hills are igneous rocks ejected from a volcano, one of many perhaps larger than Etna that once towered above the western coast of Scotland. The isles of Mull, Rum, Eigg, &c., are the truncated, weathered bases of volcanoes, 10,000 feet high. The promontory of Ross is famous for its red granite. Granite forms most of the Isle of Arran and the backbone of the chief of the Orkneys. The Shetlands are mainly granite, gneiss, and syenite. The mighty headland of Cape Wrath, the north-west extremity of Scotland, is granite and so is most of the north and north-east coast.

Coming to the Welsh coast we find that the basement rock of the Isle of Anglesea chiefly consists of igneous rocks and metamorphosed Pre-Cambrian rocks. The great promontory of Caernarvon is composed of the very ancient rocks of the Cambrian and Silurian formations. About St. David's Head, Strumble Head, and other parts of the Pembroke promontory, igneous rocks are extensively present. The two great promontories of Cornwall—the Land's End and the Lizard, which jut out like mighty breakwaters, are of hard igneous rocks; the Land's End being of granite and the Lizard of Serpentine. The Scilly Isles, fortunately for them, are all of granite. The rest of the west coasts of Cornwall and Devon are mainly of the Devonian formation, and consist of sandstones, slates, and limestones which have been considerably metamorphosed by the volcanic disturbances of the Devonian period. The lowest bed consists of hard sandstone grits and slates, and these form the coast about Porlock, Linton, Combe Martin, the Hangmans, Martinhoe, and Trentishoe. Hard Devonian slates and limestones form the coast about Ilfracombe, while mountain limestone forms the fine cliff of Gallantry Bower at Clovelly, and millstone grit the bold promontory of Hartland Point. You see then that the configuration and scenery of our western coast line are the direct results of its geological history and circumstances. In the terrific and incessant warfare between lofty masses of igneous and highly metamorphic, crystalline rocks on the one hand, and the destructive attacks of fierce Atlantic waves and storms on the other, the rocks have in some places stood their ground and survived the attack, in other places where softer, or where there were fractures, fissures, or weak places, the waves have made breaches and cut their way inland, or swept away altogether the opposing barriers. The west coasts of Ireland and Scotland, being exposed to the full sweep of the Atlantic, are gashed to a jagged outline throughout. "The narrow creeks, the steep cliffs, the rocky islets, return upon us again and again in endless succession, varied and modified by the varying nature of the rock masses which the ocean carves." If you examine a geological map you will find that the irregularities are, for the most part, produced by the alternation of hard and soft rocks, the former constituting the headlands, and the latter the bays. Mount's Bay, between the granite of Land's End and the Serpentine of the Lizard, has been eaten out of the softer Devonian slate formation. The picturesque rock of Mount St. Michael, in St. Michael's Bay, owes its insulated position and elevation to its being a boss of granite, while the softer slate around it has been worn away below the level of the high tide. The long inlet of the Bristol Channel has been gouged out of a long stratum of soft secondary rocks that once lay between the hard sandstone ranges of South Wales and Devonshire. Morecambe Bay has been eaten out of the soft trias sands west of the Pennine range, but if it had been exposed to the direct attack of the Atlantic, unprotected by Ireland as a breakwater, the land would have been eaten into right to the foot of the Pennine range. The estuary of the Clyde has been carved out of the soft beds of the higher Carboniferous. Every indentation and projection of the western coast line of our islands is an unmistakeable monument of countless ages of erosion. What has been left of the land and what has been taken away bear equally striking testimony to the important effects on the preservation of our island and on its coast scenery, produced by the upheaval of the oldest and hardest rocks on the Atlantic edge of the island.

(*To be continued.*)

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